

The SIS100 laser cooling facility*

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High-quality, stored ion beams can be obtained by means of electron cooling and/or stochastic cooling. At intermediate kinetic energies ($\gamma \approx 1$), these methods work very well. But at very high kinetic energies ($\gamma > 5$), they become less effective. For instance, to reach electron cooling at $\gamma = 12$, a very sophisticated (voltage up to 6 MV) and thus expensive electron cooling system is required. Therefore, another method was considered for the FAIR heavy-ion synchrotron SIS100: Laser cooling of bunched ion beams. Based on successful experiments with stored, relativistic heavy-ion beams at the ESR [1], it was (2013) decided to set up a laser cooling facility at the SIS100. Within the 3rd term of the Programme Oriented Funding (POFIII) of the Helmholtz Society, we wrote a proposal for this facility as part of accelerator research and development (ARD) within "Matter and Technologies" [2]. Early 2014, the proposal was approved and received the highest marks ('highlight').

Within FAIR@GSI primary beams, a special project group 'SIS100 laser cooling' (PSP-code 2.8.10) was formed, which tasks are to specify, design, order, construct, setup, and test the SIS100 laser cooling facility. (Note: The planned laser cooling facility can serve both the SIS100 and the future SIS300.) The project group consists of scientists from SPARC 'laser cooling' [3], which come from GSI and the collaborating partner universities and research centers in Dresden-Rossendorf, Darmstadt, Jena, Münster, and Lanzhou (China).

For laser cooling at the SIS100, the setup must be similar to that used at the ESR, and at least contain a laser system with a beamline (incl. optics and diagnostics), a set of scrapers, a buncher (exciter), and a dedicated fluorescence detection system. The facility will be located 20 m underground (see Fig.1). The laser light will be transported from the laser lab in the (inner) service tunnel to the (outer) accelerator tunnel, passing through concrete walls and a thick layer of soil between the two tunnels. This laser beamline (length 25 m, diameter 20 cm) should be made out of stainless steel vacuum tubes. Vacuum conditions are required to transport the laser light, which covers a very broad spectrum ranging from the IR ($\lambda \sim \mu\text{m}$) down to the XUV range ($\lambda \sim \text{nm}$). The laser lab (180 m²) will contain a special cleanroom (50 m²) to operate the laser systems. There will also be a detector cave (45 m²) in which special

detector systems for x-ray measurements can be installed (SIS300). Detectors for the IR- to the XUV-range are still compact enough to fit into the SIS100 tunnel. To couple the laser light in and out of the accelerator, special vacuum chambers with optics and diagnostics will be used. Spatial overlap (about 25 m) between laser and ion beam needs to be adjusted using scrapers and reference points.

First tests of the facility will use Li-like ions and laser systems provided by the groups in Darmstadt and Dresden. Once the facility has passed all the tests, and first laser cooling has been demonstrated, other ion species and/or laser systems could be used as well. We emphasize that also laser spectroscopy experiments can be performed! Once the cooling transition is found, it can also precisely be measured. Ultracold beams are also of great interest by themselves. Last, but not least, it will be attempted to extract the laser-cooled ions from the SIS100 and uniquely deliver very cold and very short ultra-relativistic ion bunches to experiments.

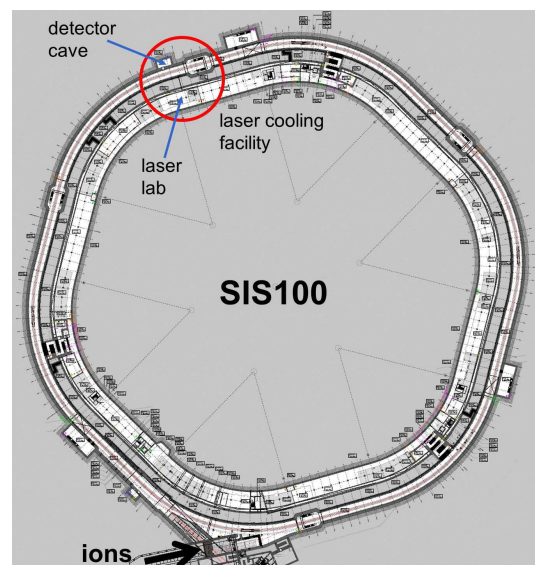


Figure 1: The FAIR heavy-ion synchrotron SIS100. The planned laser cooling facility is indicated by the red circle.

References

- [1] U. Schramm *et al.*, Prog. Part. Nucl. Phys. **53** 583 (2004).
- [2] <https://www.helmholtz-ard.de/e25/>
- [3] <https://www.gsi.de/sparc>

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